Lock-in Carrierography (Photocarrier Radiometric Imaging) of defects and dislocations in industrial Si solar cells

Andreas Mandelis [(*)]

Center for Advanced Diffusion-Wave Technologies (CADIFT),

Department of Mechanical and Industrial Engineering, University of Toronto, Ontario

M5S 3G8, Canada

Abstract

Modulated photocarrier radiometric (PCR) imaging ("lock-in carrierography") is a novel dynamic NDT imaging methodology for the characterization of optoelectronic defects in industrial multicrystalline and single-crystalline silicon solar cells [1]. Lock-in carrierography maps the charge carrier-wave density field across the device and will be presented as the evolution of optoelectronic semiconductor substrate Si PCR imaging. It can be implemented using a NIR InGaAs camera and a spread superbandgap laser beam as a photocarrier source at low modulation frequencies (< 10 Hz) or using point-by-point scanning PCR imaging with a focused laser beam at high (kHz) frequencies. Carrierographic images can be supplemented by quantitative PCR frequency scans [2]. The ac photovoltage and the PCR signals were measured simultaneously as functions of modulation frequency, excitation intensity, external dc illumination and load resistance. The instrumental aspects and image controlling optoelectronic parameters will be discussed. The influence of base recombination lifetime and junction capacitance on the PCR and ac photovoltage signals will also be discussed. Solar cell lock-in carrierography will be compared to NIR optical reflectance, modulated electroluminescence (MEL) and modulated photovoltage (MPV) imaging. Non-contact carrierographic imaging is controlled by the photo-excited carrier diffusion wave and exhibits similar features to contacting MEL and MPV images. Among these methods carrierography exhibits the highest contrast and sensitivity to mechanical and crystalline defects in the substrate at

lock-in image frequencies in the range of the inverse recombination lifetime in the quasi-neutral region (bulk).

[1] A. Melnikov, A. Mandelis, J. Tolev, P. Chen and S. Huq, “Infrared lock-in carrierography (Photocarrier radiometric imaging) of Si solar cells (J. Appl. Phys. **107**, 114513 (1 – 11), 2010.

[2] A. Mandelis, J. Batista and D. Shaughnessy, "Infrared photo-carrier radiometry of semiconductors: Physical principles, quantitative depth profilometry and scanning imaging of deep sub-surface electronic defects", Phys. Rev. B **67**, 205208-1-18 (May 2003).

(*) Contributors: A. Melnikov, P. Chen, S. Huq